Utility Scale Wind on Islands

An Economic Feasibility Study of Ilio Point, Hawaii

The opportunity now exists for the development of a utility-scale wind farm in Hawai'i. Examining the current technical and economic environment leads to the conclusion that wind generated electricity has a sizeable cost advantage over Hawai'i's traditional petroleum fueled generation. Keith M. Stockton, University of Colorado describes an economic feasibility study of a potential utility scale wind site in Hawai'i.

Hawai'i is striving to increase the high technology components of its economy. However, a potential limitation to economic growth is the high cost of electricity. Hawaiian electricity users pay the highest rate in the United States at 13.0 cents/kWh, a premium of 80% over the national average. This premium acts as a competitive disadvantage to businesses in Hawai'i compared to mainland-based firms. This disadvantage is especially noteworthy on the island of O'ahu, the state's commercial centre and home to nearly 75% of the population. O'ahu is heavily dependent on the use of residual fuel in electricity generation. Residual fuel is the component of crude oil remaining after the refining process. Approximately 85% of O'ahu's total electricity generation is residual fueled. Generation from renewable sources accounts for just 4% of generating capacity, primarily from a single biomass facility. In addition to its natural beauty, Hawai'i's endowment includes a large potential for wind-generated electricity. Northeast trade winds consistently flow over the islands.

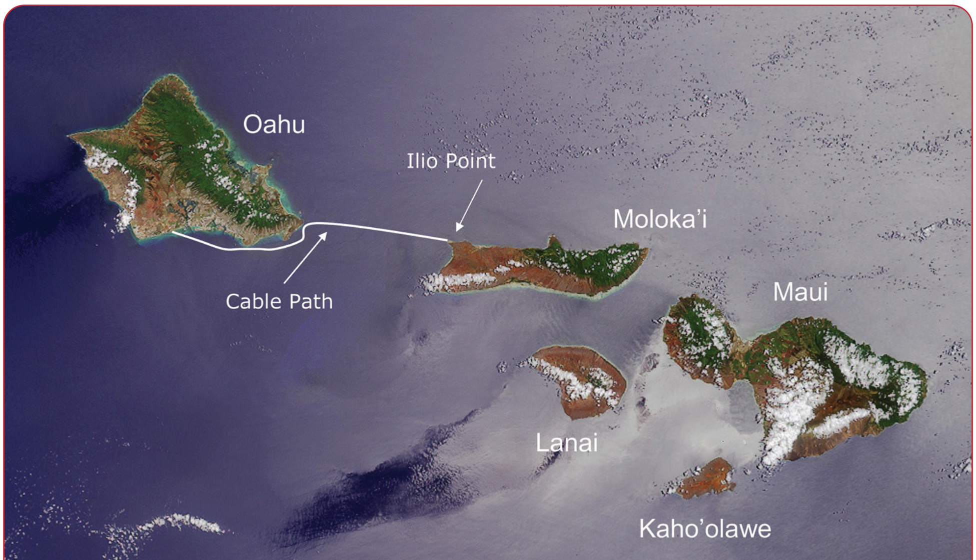

Figure 1: Location of Ilio Point Wind Farm and undersea transmission cable.

In 1995, Global Energy Concepts (GEC) conducted a renewable energy resource study for the State of Hawai'i. High profile view shed impacts have limited wind energy development on O'ahu. However, GEC identified a suitable site near Ilio Point on the neighbouring island of Moloka'i. In describing the site, GEC stated, "Most of the non-coastal lands of west Moloka'i are agricultural lands with acceptable zoning for wind energy development. There are no problems anticipated with potential development in this area with respect to terrain, landowner or public acceptance. Environmental and cultural resources exist in this area; however, there is a large amount of land with significant wind resource available and with appropriate siting, conflicts should be avoidable." Still, GEC found that utility-scale projects were unlikely to be developed on Moloka'i because of insufficient local demand (<15MW) and the lack of interisland transmission capability. GEC did not address the possibility of exporting Moloka'i wind generated power to O'ahu.

The high potential site identified by GEC lies near Ilio Point in west Moloka'i (See Table 1). Although this data is incomplete, it is clear that significant wind resources are present at Ilio Point. The United States National Renewable Energy Laboratory (NREL) classifies the Ilio Point area as a Class 6 (6.4 m/s @ 10 m height) wind resource site.

This study assesses the economic feasibility of installing a utility-scale wind farm at the Ilio Point site and exporting the electricity to O'ahu via a new undersea transmission system. Supporting this proposal are changes in four factors since the 1995 GEC study. First, the cost of residual oil has nearly doubled since 1995. Second, the cost of capital has decreased. Third, wind power technology has improved greatly, resulting in considerably decreased wind power costs. Finally, the Hawai'i State Legislature passed a renewable portfolio standard in June 2001 requiring that 9% of net electricity sales come from renewable sources by 2010. Increased production of wind energy is a key component in meeting the standard. The view of this study is that today's technical and economic environments make it feasible to construct a utility-scale wind farm on the Ilio Point site (Figure 1).

Assumptions

In order to maximize economic efficiency, the study conducts analysis based on a utility-scale wind farm with a 180 MW capacity, representing 10% of the present O'ahu generating capacity. The Net Cost of Energy equation used in the study follows NREL guidelines as shown in Figure 2. The study specifies the use of the Vestas V80-1.80 MW wind turbine. Accordingly, 100 turbines will be necessary to meet the 180 MW capacity defined in the study. A key parameter in the economic feasibility of any wind farm is the capacity factor. The study assumes NREL's conservative capacity factor of 40% for Class 6 wind farm sites. Based on the 180 MW capacity and a capacity factor of 40%, the Ilio Point project will deliver 630,720 MWh per year to the O'ahu grid.

Initial capital costs

Wind farm

The initial capital costs of the wind farm portion of the project include a number of material and construction costs. The following unit turbine and tower costs were used:

Rotor and nacelle:	$1,100,000
Tower:	$205,000
Delivery to Moloka'i:	$145,000
Total Delivered Cost/Unit	$1,450,000
Total Delivered Cost	$145,000,000

Net COE = ICC/AEPnet + (LLC + O&M + LRC + Misc. Costs) - PTC

Where:
Net COE = Levelized Cost of Energy $/kWh (constant dollar)
ICC = Initial Capital Cost Annual Debt Service
AEPnet = Net Annual Energy Production (kWh/yr)
LLC = Land Lease Expense/kWh
O&M = Levelized O&M Expense/kWh
LRC = Levelized Replacement/Overhaul Expense/kWh
Misc. Costs = Miscellaneous Operating Expense/kWh
PTC = United States Production Tax Credit/kWh

Figure 2: The Net Cost of Energy equation used in the study follows NREL guidelines

Balance-of-Station capital costs are substantial and are detailed in Table 2. The table includes details of costs for foundations and construction/erection. Remaining inflation adjusted Balance-of-Station costs were derived using conservative estimates from GEC's November 2000 Update of Selected Cost and Performance Estimates. The Ilio Point wind farm total Balance-of-Station cost is 143% of the comparable value for a U.S. mainland wind farm. The $28 million premium over the mainland wind farm cost reflects the additional expense associated with wind farm construction on an island with little industrial infrastructure.

Future Ilio Point studies should include detailed analysis of two construction issues. First, the Ilio Point location is relatively undeveloped. Although that feature is a positive aspect of wind farm development, the lack of a high capacity power grid and major roads may present engineering challenges. Second, a large crane is required to erect the Vestas V80-1.8 MW turbine because the nacelles will be up to 78 meters in height. Engineering studies should include detailed plans regarding construction crane requirements and the associated harbour and road infrastructure. Fortunately, less costly construction techniques using self-erecting tower and nacelles may become viable in the future. NREL's paper, "WindPACT Turbine Design Scaling Studies Technical Area 3 – Self-Erecting Tower and Nacelle Feasibility" describes several of these techniques in detail.

Transmission system

The proposed Ilio Point wind farm exports its electricity to the O'ahu grid via a new undersea transmission system crossing the Kawai Channel between Moloka'i and O'ahu. Alan Laxson of NREL and Mike Bahrman of ABB Power Technology recommend a High Voltage Direct Current (HVDC) Light solution. One significant advantage of the HVDC Light cable in the Ilio Point project is that its strength, flexibility and low weight allow installation in deep water and on rough bottoms. Proven HVDC Light installations occur in water up to 1000 meters deep, significantly deeper than the 671 meter depth of the Kawai Channel.

The costs of the undersea cable and the related substations are a considerable addition to the project. The turnkey cost of the two converter substations (AC to DC on Moloka'i, DC to AC on O'ahu), is estimated by ABB Power Technology at $200/kW or $36,000,000 for the 180 MW project. Cable cost, including installation, is $80,000/km. The undersea distance from Ilio Point to O'ahu grid insertion at the present generating stations near Pearl Harbor is 90 km, resulting in a cable cost of $7,200,000. An additional 20% contingency covers potential costs of directional drilling, irregular seabed formations, cable burial near shorelines and substation land costs. The total initial capital cost of the transmission system is $51,800,000. Combining the wind farm and transmission system initial capital costs results in a total initial capital cost of $290,700,000.

Table 1: Ilio Point wind speeds

Height (M)	Winter		Spring		Summer		Autumn	
	Speed (m/s)	Power (watt/m^2)	Speed (m/s)	Power (watt/m^2)	Speed (m/s)	Power (watt/m^2)	Speed (m/s)	Power (watt/m^2)
45.7	9.3	752*	10.5	878*	13.8	1746*	N/A	N/A
30.0	5.2	211*	7.9	445*	10.5	766*	N/A	N/A
9.1	5.3	240*	7.8	415*	8.2	402*	N/A	N/A

*Mean wind speed and power based on less than 75% data recovery for the period

Financing

The study assumes that Hawaiian Electric Industries (HEI) finances the initial capital cost of the project through long-term debt. The debt length coincides with the projected 30-year project life. HEI 30-year corporate debt carries an interest rate of 6.71%, resulting in an annual debt service of $22,750,000 on the $290,700,000 total initial capital cost. Converting this payment to a per kWh basis, initial capital costs are 3.61 cents per kWh.

Annual operating expenses

Annual Operating Expense (AOE) includes four components: Land Lease Cost (LLC), Levelized O&M Cost (O&M), Levelized Replacement/Overhaul Cost (LRC) and miscellaneous costs.

Land lease cost

In the 2000 study, GEC studied a site comparable to Ilio Point at Lalamilo Wells on the Big Island of Hawai'i. The inflation adjusted GEC estimate for LLC at Lalamilo Wells is $2,450/year/turbine. Total LLC for the Ilio Point project is therefore $245,000/year or 0.04 cents/kWh.

Operation and maintenance cost

The majority of O&M cost is associated with maintenance. Maintenance cost includes:

- The costs of unscheduled but statistically-predictable, routine maintenance visits to cure wind turbine malfunctions
- The costs of scheduled preventive maintenance for the wind turbines and the power collection system
- The costs of scheduled major overhauls and subsystem replacements

The first two of these occur during the course of a year and are included in O&M cost. The third occurs at intervals of five to 15 years, involves a financial accrual over the intervening years and thus is the LRC cost component. The National Wind Coordinating Committee's (NWCC) 1997 report, "Wind Energy Costs", shows that the inflation adjusted maintenance cost of a modern wind turbine is 1.0 cents/kWh. The major component of the total maintenance cost is unscheduled maintenance, resulting in the following apportionment:

Unscheduled Maintenance	0.75 cents/kWh
Preventative Maintenance	0.25 cents/kWh
Total Maintenance	1.00 cents/kWh

Levelized replacement costs

Levelized replacement cost relates to the major overhaul of wind turbines that occurs every five to 15 years. Because this cost occurs at intervals of several years and not routinely during each year, correct accounting requires an annual accrual of funds. The objective of this accrual is to have the funds available when the need for overhaul or replacement occurs. When adjusted for inflation since 1997, the NWCC estimates result in a 2003 LRC of 0.05 cents/kWh.

Miscellaneous operating cost

Miscellaneous operating expense includes property taxes, insurance, substation maintenance and general management fees. When adjusted for inflation, the NWCC estimates result in total current miscellaneous costs of 0.32 cents/kWh.

Total annual operating expense (AOE)

Annual Operating Expense includes LLC, O&M, LRC and other miscellaneous fees.

AOE = LLC + O&M + LRC + Miscellaneous Expense

For the Ilio Point project, this expense equals:

AOE = 0.04 + 1.0 + 0.05 + 0.32 = 1.41 cents/kWh

Cost summary

The Net Cost of Energy calculation is the sum of the Initial Capital Costs and the Annual Operating Costs less the US Production Tax Credit. Conservative values in the Net COE equation include GEC's conservative cost estimates, NREL's conservative capacity factor, and substantial budget contingencies on wind farm and transmission system capital.

For the Ilio Point project:

Initial Capital Costs	=	3.61 cents/kWh
Annual Operating Costs	=	1.41 cents/kWh
Gross Cost of Energy	=	3.61 + 1.41= 5.02 cents/kWh
U.S. Federal Production Tax Credit	=	-1.8 cents/kWh
Net Cost of Energy	=	3.22 cents/kWh

Note that potential interest and accelerated depreciation tax benefits are not included. It is possible that upon further detailed analysis, the Net Cost of Energy will be lower than the 3.22 cents/kWh calculated above.

Petroleum-fueled generation expense

The economic viability of the Ilio Point wind farm depends on the comparison to electricity generation costs from current O'ahu based residual fueled generation. However, this study makes no assumptions regarding the future price of residual petroleum. Instead, the study examines Ilio Point Net COE compared to a range of residual petroleum prices. Hawaiian Electric Company (HECO), the

Table 2: Balance-of-Station capital costs

Electrical Infrastructure	$15,750,000
Construction/erection	$12,500,000
Foundations	$10,000,000
Sub-Station	$9,000,000
Roads & Grading	$1,825,000
Legal Fees & Permitting	$1,000,000
Control System	$350,000
Control Buildings	$225,000
Central Buildings	$125,000
Engineering & Overhead	$13,525,000
Project Contingency	$16,750,000
Initial Supplies	$12,850,000
Total Balance-of-Station Costs	$93,900,000

Notes:Engineering and Overhead is assumed to be 7% of the all on-site processing and generating units, including all direct and indirect construction costs. Project Contingency is 8% of the sum of all costs and covers the cost of additional equipment or unexpected costs overlooked in a preliminary cost estimate. Initial Costs reflect the cost of supplies needed on hand to begin operating the power plant. These costs account for last minute changes and the capital required for inventory of spare parts, fuel on hand, or other miscellaneous expenses.

power provider for the island of O'ahu and a subsidiary of HEI, obtains 95% of its electricity from five generating facilities. HECO has supply contracts with two independently owned power production facilities. Analysis of residual fueled generating costs focuses solely on the three HECO owned facilities. Historical HECO data shows that each dollar in the price of a barrel of residual petroleum translates into 0.174 cents in the price of one kWh. For example, residual petroleum at $30/barrel equates to a fuel expense of 5.22 (30 x 0.174) cents/kWh. According to Gary Hashiro of HECO, variable O&M costs for HECO residual fueled generation are 0.04 cents/kWh.

For this comparison, the Ilio Point wind farm receives zero capacity credit. In other words, there are no offsetting savings from the reduction of existing or planned residual fueled generating facilities. The residual fueled generating facilities incur fixed O&M, replacement and future expansion costs regardless of the status of the Ilio Point facility. Only fuel and variable O&M costs provide offsetting savings to Ilio Point generation.

By analysing the relationship between electricity costs from the Ilio Point facility delivered to the O'ahu grid and current residual fueled generating costs, the crossover point is $18.30/barrel. HECO residual petroleum prices averaged $27.95/barrel in 2002. At that fuel cost, the Ilio Point facility delivers electricity to the O'ahu grid at a cost 34% less than residual fueled generation.

Conclusions

It is important to note that this study uses conservative methodologies including values for capacity factor, capacity credit and Balance-of-Station capital costs. Large project contingencies act as buffers for cost overruns. Potential sizeable tax related interest and accelerated depreciation benefits are not included because of their complexity. Therefore, significant Cost of Energy reductions may take place during further detailed analysis and project bidding.

The study focused on the economic viability of the Ilio Point facility and purposely refrained from analysis on contentious issues. Many questions remain unanswered. Will Moloka'i residents support a large commercial operation on their rural island? Are landowners near Ilio Point willing to enter into long-term leases? What is the view shed impact to Moloka'i residents of a wind farm containing 100 turbines over 1700 hectares? How will requirements of HECO's residual oil supply contracts affect the fuel cost savings from the wind farm? Is HECO in the financial position to support a capital investment of nearly $300 million? Can Renewable Energy Credits decrease the Ilio Point Net COE? Further professional analysis should answer these questions.

This study reveals that it is sound to begin serious discussion among industry and government leaders regarding the economic feasibility of constructing the Ilio Point wind farm. The potential savings to O'ahu ratepayers form a foundation from which to pursue additional detailed analysis. The energy industry is a valuable partner in making Hawai'i more competitive in the high tech economy of the 21st century. The Ilio Point project is a key initiative in that partnership.

Contact: Keith M. Stockton, Environmental Energy Policy Program, Office of Environmental Studies, University of Colorado, Boulder, CO 80309, USA. Tel: +1-303-771-1427. E-mail: kestock@msn.com